It may not be uninteresting to add that, while my experiments were in progress, I discovered that, by waiting until the evening was dark enough, I could, with a power of 154 (or, in fact, any other—but this is the one with which I make the discovery) distinctly make a quasi-phosphorescent body of *Venus* out of the blue light resulting from the very slight over-correction of my object-glass. This "dark limb" was quite startling in its apparent objectivity; but, as pointed out by Mr. Green in his oral address at our April meeting, it vanished completely on hiding the illuminated crescent.

Forest Lodge, Maresfield,
1876, *May* 27.

Photometric Experiments upon the Light of Venus.

By John I. Plummer, Esq.

The planets *Venus* and *Jupiter*, it is well known, are frequently sufficiently bright when favourably situated to cast a well-defined shadow, but hitherto advantage has not been taken of this circumstance to determine the relative intensities of their light to that of the Full Moon, nor to compare it with any standard terrestrial source of light. The following experiments and observations have been attempted with a twofold purpose: First, to ascertain whether this troublesome problem might not be attacked successfully from a new point of view, so that estimates of relative brilliancy may be made in the simple manner I have to describe as reliable as those made with costly photometers; and secondly, to determine by observation alone the variations in the amount of light reflected from *Venus* towards the Earth at its various phases. As photometric comparisons are known to be liable to much error, and are necessarily affected by the peculiarities of vision of the observer, it may be thought desirable that they should be made not only in as many different ways, but by as many different persons as possible. This is my excuse for attempting a problem various portions of which have received the attention of Herschel, Bond, Zöllner, and still more particularly of Seidel. Moreover, *Venus*, owing to its close proximity to the Sun, has had less attention paid to it than any other, while its brightness is such that it is most suitable for the direct comparison of shadows.

The plan that I have adopted has been to compare the light of the planet with that of a standard sperm candle burning 120 grains of wax per hour, and to vary the distance of this until the shadow it casts upon a screen of white paper has an equal degree of intensity to that given by the planet. It being found impossible to get the two shadows upon the same screen, separate screens were arranged for each, and brought as near to each other as possible. The arrangement was therefore a modification of Rumford's photometer. The objects of which the shadows were

observed were two equal cylindrical steel wires of $\frac{1}{14}$-inch diameter, placed in a dark room nine feet in front their respective screens; but the judgment was further assisted by noting also the shadows of the wooden laths to which the wires were attached, and of which the thickness was about $\frac{1}{2}$-inch. These conditions were preserved throughout the whole of the observations. To protect the candle from wind, it being necessarily placed in the open air, it was fixed within a lantern, which was itself enclosed, except upon one side, in a rough wooden box painted a dull black. These precautions are believed to have been sufficient for their purpose.

That in dealing with the light of *Venus* and the shadow which it is capable of throwing upon a screen properly situated we have not to deal with a faint or doubtful trace, the following facts may be noted: Thus on March 29, the Moon being four days old and within 12° of Venus, the light from each was received upon the same screen, and the shadow from *Venus*-light was still conspicuously visible. Upon the same evening *Sirius*, though having a light-intensity about $\frac{1}{9}$th that of *Venus*, was also observed to cast an appreciable shadow, the direct light of the Moon being, of course, excluded from the room in this case. That *Sirius* is sufficiently bright to produce a definite illumination upon a screen has not, I believe, been previously observed; and I may mention here that there would seem to be no difficulty in determining by this method the relative brilliancy of those planets which exceed *Sirius* in brightness; and I have been deterred from at present extending this investigation to *Jupiter* and *Mars* only by the impossibility of obtaining a sufficient range through which to vary the distance of the candle. On April 26, the light of *Venus* and of the young Moon were observed to fall upon a plaster wall in the open air, and the shadows of neighbouring buildings referable to each of these bodies were distinctly observable at the same time. For obvious reasons, no observations have been taken when the Moon was near full; and only on one occasion an observation was taken when the Moon was above the horizon; but there would not have been the least difficulty in continuing the observations under all circumstances. The following comparisons have been made:—

1876.	h m	Observed Distance of Candle. Feet.	Calculated Altitude of ♀ ° ′	Log C= Log $\frac{\text{♀ corrd. for extinct.}}{\text{Candle at 1 ft. dist.}}$	Log C $\frac{r^2\Delta^2}{r_0{}^2\Delta_0{}^2}$	Phase of ♀ v °
Mar. 20	8 40	290·65	12 42	5·1715	5·2198	114·9
„ 24	8 44	334·5	13 31	5·0314	5·0561	113·1
Apr. 14	8 52	286·25	19 41	5·0636	4·9458	102·5
„ 21	8 59	263·75	20 20	5·1269	4·9537	98·9
„ 23	9 6	265·0	19 38	5·1322	4·9423	97·9
„ 26	9 22	306·0	17 50	[5·0311]	[4·8153]	96·4
May 11	9 46	275·42	15 30	5·1605	4·8013	84·1
„ 13	10 26	314·19	6 37	[5·3623]	[4·9817]	83·2

Upon all these occasions the sky has been brilliantly clear and the equality of the shadows has been considered satisfactory by at least two persons. The probable error of a single determination is believed not to exceed 6 feet. The correction for extinction of light by the atmosphere has been obtained from Seidel's Table, but in order to be as independent as possible of arbitrary constants those corrections only have been applied to reduce the results to an uniform altitude of 18°, which is nearly the mean of the observations. Rejecting the results obtained on April 26 and May 13 (the first because the Moon was shining at the time of comparison, and the second because *Venus* was very low and appears to be over-corrected for extinction), and taking the means of results on March 20, 24, and April 14, 21, 23, we obtain the ratios $\frac{1}{78152{\cdot}5}$, $\frac{1}{77861{\cdot}0}$, $\frac{1}{69101{\cdot}9}$, to express the relation of *Venus* light to that of the candle at the distance of one foot when the illuminated portion of the planet is 114°, 100°, and 84° respectively, showing that *Venus* approaches its point of maximum brilliancy on June 6 very gradually indeed. Or taking the mean of the six comparisons, we have the light of *Venus* when 101°·9 of its illuminated disk is turned towards us and its altitude is 18°, equivalent to that of a sperm candle at the distance of 276·3 feet and its intensity equal to $\frac{1}{276{\cdot}3^2} = \frac{1}{76343}$ part of that of the candle at the distance one foot.

The next step was to reduce the values obtained (Column IV.) to some assumed distance of *Venus* from the Sun and Earth, and to exhibit the comparison of light intensities affected only by the changing phase. The distances assumed for this purpose r_o and Δ_o are 0·7184 and 1·0000 respectively, and the results are given in column V. I have then compared, by means of a graphical construction (see Diagram), the curve that best satisfies the observations with those yielded by both Lambert's and Euler's formulæ, taking the intensity of light when $v = 84°{\cdot}1$ as unity; and, although the interval of time over which the observations extend is too limited to admit of a definite conclusion being drawn, they appear to indicate that *Venus*, like the Moon, increases in brightness as it approaches the full phase much more rapidly than can be accounted for upon theoretical considerations only. It will be seen also that Lambert's formula much more nearly satisfies the observations than does Euler's. Some further evidence on this point may possibly be obtained after the inferior conjunction, when the twilight being of shorter duration will interfere less with the observations.

To obtain results independent of any terrestrial source of light it was necessary to compare the sperm candle that had been employed in the observations of *Venus* with the Full Moon, and to do this it was found more convenient to have recourse to the principle of Bunsen's photometer. The comparisons were effected upon April 8 and May 7, and they have

been treated in precisely the same way as those of *Venus*, except that in addition a small correction has been applied to reduce the light of the Moon on May 7 to the full phase. No such correction is needed on April 8. Euler's formula $\left(\theta = \sin^2 \frac{1}{2} v\right)$ has been used for this purpose. The results are tolerably accordant, giving the light of the Full Moon at the altitude of 18°, its semi-diameter being 934″·67, equivalent to that of the candle at distances of $8^{ft.}888$ and $8^{ft.}641$, or giving weight, according to the number of comparisons on each evening, of $8^{ft.}722$. Combining this value with that of the mean of the observations of *Venus*, we have,

$$\frac{\text{Actual Light of } Venus\ (v = 101^\circ\cdot 9)}{\text{Mean Full Moon}} = \frac{1}{1004}.$$

A more accurate mode of treatment would probably be to reduce each observation separately to some standard phase, and take the mean of the results. Assuming, as Seidel has done, that *Venus* attains its greatest brilliancy when $v = 76^\circ\cdot 13'\cdot 5$, $\Delta = 0{\cdot}53944$, and $r = 0{\cdot}7233$, and using Lambert's formula

$$\left(\theta = \frac{\sin v - v \cos v}{\sin v_0 - v_0 \cos v_0}\right)$$

to effect the reduction we obtain

$$\frac{Venus \text{ at greatest brilliancy (alt. } 18^\circ)}{\text{Standard sperm candle at 1 foot dist.}} = \frac{1}{60813\cdot 8} = \frac{1}{246\cdot 6^2}.$$

If the suspicion to which I have alluded be correct, that Lambert's formula is not strictly applicable to *Venus*, this result will, of course, be slightly in excess of the truth. Again, introducing the above-determined value of the mean Full Moon, we have

$$\frac{Venus \text{ at greatest brilliancy}}{\text{Mean Full Moon}} = \frac{1}{799\cdot 5}.$$

I have not been able to find any previous comparison of *Venus* with the Full Moon with which to compare this result, except what may be inferred from Bond's observations (*Memoirs of the American Academy*, vol. viii.), which give the light of *Jupiter* at mean opposition equal to $\frac{1}{6430}$, that of the mean Full Moon, and the ratio of the light of *Venus* at greatest brilliancy to *Jupiter* as 4·864 to 1, which differs only very slightly from Seidel's comparison of these two planets. This would yield the ratio $\frac{1}{1322}$ as comparable with my result; or, in other words, I attribute to *Venus* a brilliancy about 65 per cent. greater than

Bond has found. Since the methods employed are entirely dissimilar, and since Bond's investigation has chiefly to do with the Moon and *Jupiter*, both of which he has observed at altitudes generally much greater than those at which the observation of *Venus* is possible, this discordance does not prove much.

Orwell Park Observatory, near Ipswich,
1876, *June* 1.

On the Proper Motion of Bright Spots on Jupiter.
By John Brett, Esq.

There have recently appeared upon the disk of *Jupiter* two bright spots, of such distinctness and isolation as peculiarly adapt them for measurement, with a view to determine either the rotation of the planet, or their own proper motion.

I beg leave to lay before the Society the record of four observations of these spots, forming a series extending over a period of 286 hours 20 minutes of mean time, and to ask whether they afford evidence of proper motion, or whether, on the other hand, they tend to cast any doubt on the accepted rotation of the planet. There were several peculiarities about these two spots which seem to me to give them an eminent claim to attention. They occurred very near to the equator, and were very well defined, and free from entanglement with other markings: an advantage which they have maintained with singular uniformity throughout the period mentioned; but the special peculiarity to which attention is asked is, that during an interval of five days they remained in the same relative position, without any variation whatever.

Their stability in respect of latitude during those five days is undoubted; but the question is, whether or not they were equally stable in longitude. This remark only applies to the first five days of the series, because at the end of twelve days a certain deviation was obvious, as may be seen from the drawings which accompany this paper.

The drawings are fairly accurate, and I have no excuse to offer for them if they are not so. It is more easy for a practised draughtsman to detect differences of position or extension by the unassisted eye than by the micrometer-wire; and this is especially true of such delicate phenomena as planetary markings.

The first observation was made on May 23rd, 1876, at $11^h\ 30^m$ G.M.T., and is recorded by the drawing marked A.

The second observation, May 28, 1876, at $10^h\ 30^m$ G.M.T., by the drawing B.

The distance between the two spots occupies about 42° of Jovian longitude, or about 33,000 miles. Their diameter is nearly